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28 July 1969

Materiel Test Procedure 10-2-067
General Equipment Test Activity

U. S. ARMY TEST AND EVALUATION COMMAND
COMMODITY ENGINEERING TEST PROCEDURE

BOILERS, STEAM AND HIGH TEMPERATURE WATER

(20)

1. OBJECTIVE

This document provides test methods and techniques necessary to determine the technical performance and safety characteristics of boilers and their associated tools and equipment as described in Qualitative Materiel Requirements (QMR's), Small Development Requirements (SDR's), Technical Characteristics (TC's) and to determine the item's suitability for service tests.

2. BACKGROUND

A requirement exists for a device which can produce and deliver steam or high temperature water for consumption by other systems such as power generating steam turbines. This device is preferably termed a "steam generating unit" but is more commonly referred to as a "boiler". There is a wide range in the internal design and the input-output characteristics of boilers. When considered as an operating system, however, all boilers function in theory and practice in a similar manner. Fuel (input), having a specific unit volume heat content is delivered to the system at a particular rate. The fuel combines with air, also delivered at a specific rate, in the burner section. Ignition is provided for the mixture and combustion occurs in the firebox section. The primary product of combustion, heat, is transferred through the heating surface to the water or water vapor (also delivered to the heating surface at a specified rate) resulting in heated water or steam (output) which is transported out for external use. The secondary products of combustion, gases, etc., are vented to the flue section. The above describes the essentials for a boiler system. Many boilers have added features such as preheaters, super-heaters or economizers which attempt to increase the system efficiency by using the products of combustion on air, vapor, or water to produce supplementary effects.

In order to determine the effectiveness of the boilers as a device its characteristics must be compared to the characteristics of a theoretically 100% efficient system functioning in the same manner. In this theoretical system it will be assumed that the following hold true: (1) the conditions for complete combustion are present e.g. maximum heat is liberated (2) maximum transfer of heat from the combustion chamber to the heat absorbing material is conducted and (3) the heated material is delivered without losses external to the system. The performance of the boilers as determined by testing will be a comparison against the theoretical system. Figure 1 shows the possible configurations of boiler inputs and outputs.

3. REQUIRED EQUIPMENT

- Insulation Resistance Measuring Set -500 VDC.
- Dielectric Strength Tester 0-3000 VRMS, 25-60 HZ.
- Ohmmeter.

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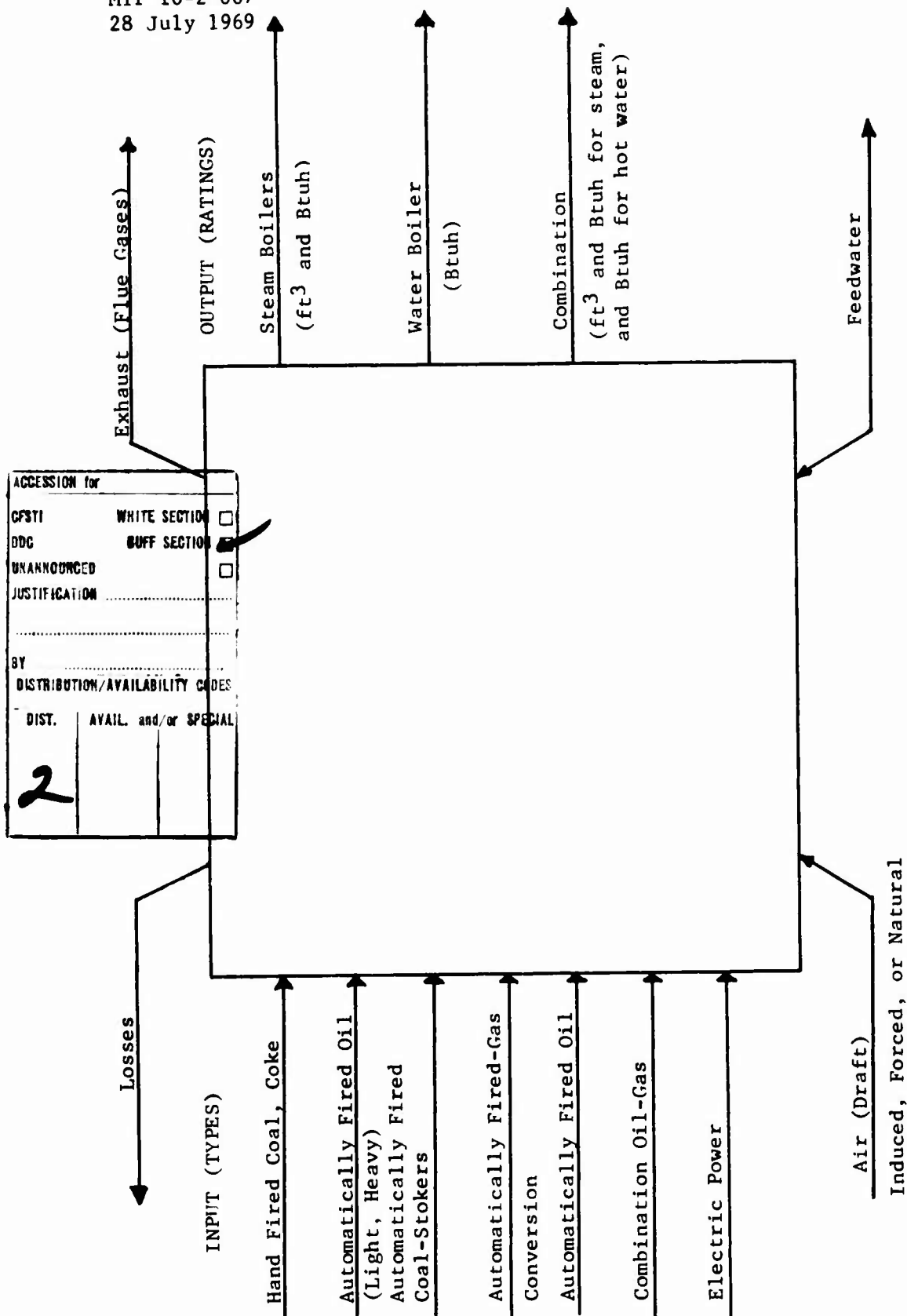


FIGURE 1. BOILER INPUT-OUTPUT CONFIGURATIONS

- d. Wheatstone Bridge.
- e. Hydrostatic Test Equipment.
- f. Pneumatic Test Equipment.
- g. Electromagnetic Interference Apparatus as required per MIL-STD-461.
- h. Vibration Amplitude Measuring Set.
- i. Sound Level Meter per ASA S1. 4-1961.
- j. Octave Band Analyzer per ASA S1. 6-1960.
- k. Applicable Boiler Test Instruments and Apparatus per ASME PTC-4.1-1964 including, as applicable:

- 1) Voltmeters, ammeters
- 2) Wattmeters
- 3) Watt-hour meters

- 1. Facilities and Equipment required in the referenced MTP's

4.

REFERENCES

- A. USATECOM Regulation 385-6, Verification of Safety of Materiel During Testing.
- B. USATECOM Regulation 700-1, Value Engineering.
- C. USATECOM Regulation 705-4, Equipment Performance Report.
- D. ASME Power Test Code Steam Generating Units American Society of Mechanical Engineers PTC 4.1-1964, with 1968 and 1969 Addenda.
- E. The Institute of Boiler and Radiator Manufacturers I-B-R Testing and Rating Code for Low Pressure Cast Iron Heating Boilers. Seventh Edition January 1967.
- F. American Boiler Manufacturers Association Packaged Firetube Boiler - Ratings for Heating Boilers 1962 Edition.
- G. The Institute of Boilers and Radiator Manufacturers SBI Testing and Rating Code for Steel Boilers Tenth Edition September 1965.
- H. American Boiler Manufacturers Association Industry Standards Engineering Information - Steam Generating Equipment 1958 Manual.
- I. Underwriters Laboratories Standards for Safety Oil Fired Boiler Assemblies UL726 November 1963.
- J. Underwriters Laboratories Gas Heating Equipment, Commercial - Industrial UL795 October 1964.
- K. ASME Boiler and Pressure Vessel Code, ASME 1965.
- L. MIL-STD-130B, Identification Marking of U. S. Military Property.
- M. MIL-B-3180B, Boilers and Related Equipment, Packaging of 20 February 1967.
- N. MIL-STD-129, Marking for Shipment and Storage.
- O. BAUMEISTER Marks' Mechanical Engineers' Handbook Sixth Edition 1964 McGraw Hill.
- P. NEMA National Electrical Manufacturer's Association Tests and Performance AC and DC Fractional and Integral Horsepower Motors Part 12 1966.
- Q. ASA S1.2-1962, Physical Measurement of Sound.
- R. ASA S1.4-1961, General Purpose Sound Level Meters.
- S. MIL-STD-461A, Electromagnetic Interference Characteristics, Requirements for Equipment.

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- T. MIL-STD-462, Electromagnetic Interference Characteristics, Measurements of.
- U. MIL-STD-463, Definitions of System of Units, Electromagnetic Interference Technology.
- V. AMCA Air Moving and Conditioning Association Bulletin 210 Standard Test Code for Air Moving Devices.
- W. NFPA National Fire Protection Association NFPA No. 70 National Electrical Code.
- X. MIL-T-704E, Treatment and Painting of Materiel.
- Y. MIL-STD-810B, Method 516 Shock Tests.
- Z. MIL-I-2819, Insulation Block, Thermal.
- AA. AR 705-15 Operation of Materiel Under Extreme Conditions of Environment.
- AB. MIL-B-17095D Boilers, Steam, High Pressure Water Tube, Packaged Type (5000 Pounds Per Hour and Over).
- AC. MIL-B-23997 Boilers, High-Temperature Water Generators, Packaged Type (Above 5,000,000 B.T.U./HR. Input Capacity).
- AD. HEL Standard S-1-63B Maximum Noise Level for Army Materiel Command Equipment June 1965.
- AE. USAGETA (HEDGE) Human Factors Evaluation Data for General Equipment November 1967.
- AF. MTP 10-2-500, Physical Characteristics.
- AG. MTP 10-2-501, Operator Training and Familiarization.
- AH. MTP 10-2-502, Durability.
- AI. MTP 10-2-503, Transportability.
- AJ. MTP 10-2-505, Human Factors Evaluation.
- AK. MTP 10-2-507, Maintenance Evaluation.
- AL. MTP 10-2-508, Safety.

5. SCOPE

5.1 SUMMARY

These procedures describe the preparations for and methods of evaluating the technical characteristics of boilers and their suitability for service testing. Due to the extensive range in the design and the internal characteristics of the boiler commodity class the following considerations concerning the tests are given in order to provide a general testing document.

1. The tests given will in general treat the boiler as a system and will measure its system characteristics.

2. Tests of components, subsystems or internal design features will not be given if their performance is inherent in the system characteristics. Where their performance is not inherent or where it must be known, tests will be made provided the component is accessible. One exception to this will be the consideration given to components or features which fall into the safety class. Due to the extremes of temperature and pressure within the boiler and the possible safety hazards present, these devices will be considered individually.

3. The size and weight of the boiler will in most cases prohibit the use of tests requiring special testing conditions. In general the tests will be

conducted with the boiler at a fixed site and allowances made, if necessary, for the testing conditions.

The tests to be conducted will consist of the following:

- a. Preparation for Test - A determination of the condition of the test item upon arrival, its physical characteristics, pre-operational checks, and operator training and familiarization requirements.
- b. Preliminary Electrical Measurements - A determination of the condition of the electrical circuits of the test item prior to the application or normal operating power. Data will also be obtained for comparisons to be made at the completion of other tests.
- c. Strength and Tightness - A preliminary check on the ability of the test item to hold the required pressures.
- d. Operation - A demonstration of the test item's controls, including sequences, safety features, and responses to various test conditions.
- e. Performance - An evaluation to determine the degree to which the test item performs its primary function. In particular the efficiency (energy balance on the input and output) and the capacity (rate and quality of the output) will be determined from the performance test.
- f. Electromagnetic Interference - An evaluation to determine the extent to which the test item produces radiated or line conducted interference.
- g. Durability - An evaluation of the test item's ability to retain original performance and physical characteristics after extended operation.
- h. Balance - An evaluation to determine the extent of undesirable motion which the test item exterior frame and components exhibit due to rotating components.
- i. Transportability - An evaluation to determine the ability of the test item to withstand the forces which it will experience during normal handling and transporting.
- j. Maintainability and Reliability Evaluation - That portion of the test which is concerned with the following: verification and appraisal of failures; determination and appraisal of maintenance characteristics and requirements; appraisal of design for maintainability; appraisal of the maintenance test package; and, calculation of indicators which express the effects of the preceding aspects.
- k. Safety - An evaluation to determine the safety characteristics and possible hazards of the test item.
- l. Human Factors Evaluation - An evaluation to determine the adequacy of the design and performance characteristics of the test item and associated equipment in terms of conformance to accepted human factors engineering design criteria.
- m. Value Analysis - An evaluation directed at analyzing the primary function and features of the test item for the purpose of reducing the cost of the test item without compromising performance and safety characteristics.

5.2 LIMITATIONS

The tests described in this materiel testing procedure are directly applicable to the evaluation of any device which intakes fuel and air, provides internal combustion and has steam, heated water, or a combination of the two as

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its output with the exception of nuclear and combined-cycle steam generators.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 Initial Inspection

6.1.1.1 Packaging Inspection

a. Visually inspect the test item container(s) and record the following:

- 1) Preservation and packaging deficiencies, based on MIL-B-3180
- 2) Evidence of packaging damage or deterioration
- 3) Container marking deficiencies, based on MIL-STD-129
- 4) Identification markings including:
 - a) Name of contractor
 - b) Date of manufacturer
 - c) Other pertinent information

b. For each package:

- 1) Measure and record the following:
 - a) Weight
 - b) Dimensions
 - c) Cubage
- 2) Record the contents of package - should include mechanical and electrical drawings and manuals containing installation, operation and maintenance data.

6.1.1.2 Inventory Check

Verify completeness of the test item and agreement between the contents of the packages and the Basic Issue Items List (BIIL).

6.1.1.3 Test Item Inspection

a. Remove the test item from its container(s). Visually inspect the test item and record the following:

- 1) Evidence of defects in:
 - a) Manufacturing
 - b) Material
 - c) Workmanship
- 2) Evidence of damage
- 3) Evidence of wear
- 4) Correlation of data on accompanying printed material with test item markings.

- 5) Identification marking deficiencies, based on MIL-STD-130
- 6) Presence of instruction plates, if applicable, including:
 - a) Identification, name and serial number
 - b) Caution instructions
 - c) Service instructions

b. Examine the test item for verification of the following and record nonconformance with requirements:

- 1) Materials, design, construction and trim of the boiler, including valves and overlimit devices, shall be in accordance with the appropriate sections of the ASME Boiler and Pressure Vessel Code.
- 2) Those locations on the boiler at which external connections are to be made shall be clearly marked and easily accessible.
- 3) Fans and blowers used in the test item shall be rated and tested in accordance with the requirements of the AMCA Standard Test Code for Air Moving Devices.
- 4) All electrical wiring and safety devices shall conform to the National Electric Code.
- 5) All motors used shall be constructed and rated in accordance with the applicable provisions of the NEMA Standards for Motors and Generators.
- 6) The test item should be mechanically strong, components securely mounted and all rotating elements shall be free.
- 7) Burner and fuel systems shall comply with the applicable Underwriters Safety Standards:
 - a) Oil fired - UL 726
 - b) Gas fired - UL 296
 - c) Combination - UL 795

6.1.2 Physical Characteristics

Determine and record the physical characteristics of the test item as described in the applicable sections of MTP 10-2-500 and the following:

- a. Materials used are non-corrosive or protected against corrosion and non-flammable.
- b. All surfaces of the test item are treated and painted in accordance with MIL-T-704.
- c. Exterior surfaces of the boiler are provided with insulation in accordance with MIL-I-2819.

6.1.3 Operator Training and Familiarization

Orient test personnel using the criteria of MTP 10-2-501 and record all pertinent data.

6.1.4 Preoperational Inspection

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Perform the following:

- a. Assemble the test item and/or attach all devices removed for shipping.
- b. Remove all preservatives and protection equipment.
- c. Lubricate those parts of the test item requiring lubrication.
- d. Verify that the test item is in satisfactory condition prior to operation including that all controls and valves to be operated during testing are free and move easily.
- e. Verify the presence of the following systems which can be either manual, automatic, or a combination:
 - 1) Programming control system to govern the starting and shutdown sequence of the boiler.
 - 2) Safety control system to prevent starts and initiate shutdowns during startups or firing in the event of an unsafe condition.
 - 3) Combustion control system to modulate the firing rate in accordance with the load demand.

6.2 TEST CONDUCT

NOTE: Prepare an Equipment Performance Report (EPR) for all equipment failures.

During the conduct of all tests, test personnel shall observe the proper safety precautions and in particular shall adhere closely to the manufacturer's instructions for bringing the boiler to and maintaining it at a normal level.

6.2.1 Preliminary Electrical Measurements.

Perform the following prior to conducting operational tests, as applicable:

6.2.1.1 Power Cables

- a. Without the power cable(s) connected to the electrical service, set the test item main power switch to the "ON" position.
- b. Using an ohmmeter, verify and record the following:
 - 1) That the earth or building ground lead connected, effectively grounds the test item.
 - 2) That each power lead of the power cable is not grounded.

6.2.1.2 Motors

- a. Disconnect the power leads to all motors (drive motors, fan motors).
- b. Using a Wheatstone bridge, measure and record the direct current resistance of each motor winding.
- c. Reconnect the motor power leads.
- d. Using a megohmmeter, measure and record the insulation resistance

between each motor winding (with its associated circuit) and the test item case (with all other circuits connected to the test item case).

e. Test the dielectric strength of each electrical circuit by applying the test voltage between the circuit and ground with all other circuits connected to ground. (See Appendix A for the applicable requirements).

NOTE: In cases where shunt components have lower voltage ratings than the test voltages, disconnect those components for steps b and e.

6.2.1.3 Fuel Oil Electric Heaters

Conduct insulation resistance and dielectric strength tests on each heater and its associated circuits as described in MIL-H-22577 when required.

6.2.2 Strength and Tightness

NOTE: This procedure is to be performed prior to firing the test item.

6.2.2.1 Preparation for Test

- a. Attach all boiler trim and appurtenances except for input-output lines.
- b. Blank-off openings, including input-output, air casings and ducts, as required.
- c. Attach high-pressure water and air supply lines and instrumentation as required.

6.2.2.2 Test Conduct

Perform the following where applicable:

- a. Hydrostatically check the watersides in accordance with the ASME Boiler and Pressure Vessel Code.
- b. Pneumatically check the air casing and ducts exterior to the furnace at maximum working pressure using the soap bubble method.
- c. Pneumatically check the gas sides of the boiler at 1 1/2 times the predicted operating pressure in the furnace for maximum continuous output. For this test the boiler will be tightly sealed and air admitted until the test pressure is reached.
- d. Hydrostatically test the fuel oil system 1 1/2 times the maximum operating pressure.
- e. Pneumatically test the gas fuel system at operating pressure using the soap bubble method.

6.2.3 Operation

Determine the operability of the test item control systems as follows:

- a. Prepare the boiler for operation, including the connection of

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input-output and control lines.

b. Operate the test item by sequencing the programming and combustion control systems through all steps involved following the manufacturer's instructions and record the following:

- 1) Difficulties encountered (i.e., loss of ignition, improper flame, etc.).
- 2) Adjustments required.

c. Perform a minimum of two cycles of operation for each safety device used in the test item, by simulating the type failure which the device is to detect, and record the following:

- 1) Device used
- 2) Failure for which device was provided
- 3) Operability of the device

6.2.4 Performance

Performance tests shall be conducted in strict accordance with the requirements of the latest ASME Power Test Code (PTC 4.1-1964) for Steam Generating Units to determine, as applicable, the test item's capacity, efficiency, and steam quality using the following methods:

- a. For Steam Generator: Input-Output Method
- b. For High Temperature Water Generator: Heat Loss Method

NOTE: 1. Capacity is defined as follows:

- a. For steam generators: Actual evaporation in pounds of steam per hour delivered or BTU per hour absorbed by the working fluid or fluids.
- b. For high temperature water generator: The heat absorbed by water in BTU per hour.

2. Efficiency is expressed as follows:

- a. For the Input-Output Method:

$$\text{Efficiency (\%)} = \frac{\text{Output}}{\text{Input}} = \frac{H(W)}{HHV \times W + H(C)} \times 100$$

- b. For the Heat-Loss Method:

$$\text{Efficiency (\%)} = \left(100 - \frac{H(L)}{W \cdot HHV + H(G)} \right) \times 100$$

where: HHV is the high heat value of the fuel
H(W) is the heat absorbed by the working fluid(s)

H(C) is the heat credit(s) (heat added to the boiler by sources other than the fuel)
H(L) is the heat loss(es)
W is the mass rate flow of fuel

NOTE: For a complete listing of H(C) and H(L) refer to the Power Test Code.

3. Steam quality of the steam generator is defined as the percentage by weight of vapor in a steam and water mixture.

6.2.4.1 Preparation for Tests

Perform the following:

- a. Ensure that all heat transfer surfaces both internal and external are commercially clean.
- b. Obtain the precise heat value for the fuel to be used.
- c. Determine the run duration as follows:
 - 1) For coal fired units using pulverized or crushed coal - a minimum of four hours.
 - 2) For stoker fired coal units - 4 hours.
 - 3) For gas or oil fired units - a minimum of 4 hours.
- d. Determine the requirements for heat credits and losses, types and locations of sensors, the method for each measurement, and procedures for computation by referring to the Power Test Code.

- NOTE:
1. A throttling or separating calorimeter may be required on the output steam line for determination of steam quality of steam generators. The type will depend on moisture content.
 2. A high-temperature water heater must be pressurized above saturation temperature to assure against the presence of steam at the point of measurement.

- e. Attach the required sensors to the boiler.
- f. Fire the boiler and bring it to rated capacity.

6.2.4.2 Test Procedures

6.2.4.2.1 Input-Output Method - Operate the test item for the prescribed period of time and perform the following:

- a. Efficiency determination; record the following:
 - 1) Fuel delivery rate
 - 2) Applicable data for heat credits to be added to the boiler

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NOTE: See Power Test Code for heat credits added.

3) For test item output determination:

- a) Water flow
- b) Steam mass flow
- c) Steam and feedwater temperatures
- d) Steam and feedwater pressures

b. For steam quality determination, record the following:

1) For throttling calorimeter:

- a) Steam pressure
- b) Steam temperature

2) For separating calorimeter:

- a) Weight of water as separated
- b) Weight of water as dry steam

c. For capacity determination, record the following as applicable:

- 1) Main steam mass flow
- 2) Reheat steam mass flow
- 3) Rate of heated water flow

6.2.4.2.2 Heat Loss Method - Operate the test item for the prescribed period of time and perform the following:

a. For efficiency determination, record the following:

- 1) Fuel delivery rate
- 2) Applicable data for heat credits to be added to the boiler

NOTE: See Power Test Code for heat credits to be added.

3) For heat losses, record the following:

a) As measured directly:

- (1) Flue gas temperature
- (2) Supplied air temperature
- (3) Fuel temperature
- (4) Temperature, pressure and quantity of auxiliary mediums
- (5) Air humidity
- (6) Radiation
- (7) Sensible heat in flue duct

- (8) Ashpot heat losses
- (9) Electric power for fans and blowers
- b) As determined by analysis:
 - (1) Orsat analysis of flue gases.
 - (2) Pulverizer rejects.
 - (3) Combustible content and quantity of dust in exit gases, collector hoppers, and ashpot refuse.
- b. For capacity determination, record the following:
 - 1) Output water line temperature
 - 2) Output water line flow rate

6.2.5 Electromagnetic Interference

Subject the test item to the applicable electromagnetic interference procedures of MIL-STD-462, for Class IIB equipment, using the equipment described in MIL-STD-461.

NOTE: General interference definitions are described in MIL-STD-463.

6.2.6 Durability

Determine the durability of the test item as described in the applicable sections of MTP 10-2-502 and the following:

6.2.6.1 Twenty four Hour Test

- a. Place the test item in a normal operating mode as described in paragraph 6.2.3.
- b. Operate the test item continuously for 24 hours at rated capacity.
- c. Record the following, using boiler attachments or appropriately placed sensors when required, hourly:

- 1) Air flow rate and temperature.
- 2) Fuel delivery rate, temperature, and pressure.
- 3) Feedwater delivery rate and temperature.
- 4) Output (steam or hot water) delivery rate, temperature and pressure.
- 5) Stack gas flow rate and temperature.
- 6) Electrical power consumption.
- 7) Other boiler attachment readings.

- d. At the completion of testing determine the effects of heat on the test item by performing the electrical measurements of paragraph 6.2.1.2 and 6.2.1.3 as applicable.

NOTE: The electrical checkout shall be performed immediately following the end of the test run while all components are very nearly at their operating temperatures.

- e. Visually examine the test item for, and record evidence of,

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deterioration and accelerated wear.

6.2.6.2 Adverse Conditions Tests

At the discretion of the test director repeat the procedures of steps c through e of paragraph 6.2.6.1 with the test item operating as follows:

- a. Performing an endurance run at reduced capacity
- b. Performing at peak load capacity for maximum short period output

6.2.7 Balance Test

- a. Place the test item in its normal operating condition at 100% load and attach a vibration amplitude measuring set, as required, to take a measurement of step b.
- b. Measure and record the amplitude of vibration in at least two places on each exposed face of the dehumidifier.
- c. Record the location of each measuring point.

NOTE: Measurements should be made at locations which are remotely removed from the point or points at which the test item is mechanically secured to its mounting.

6.2.8 Transportability

- a. Subject the test item to the applicable sections of MTP 10-2-503
- b. At the completion of each test of step a perform the following:
 - 1) Visually inspect the test item for signs of damage or deterioration.
 - 2) Subject the test item to the electrical measurements of paragraph 6.2.1.
 - 3) Subject the test item to the applicable procedures of paragraphs 6.2.3 and 6.2.4 to determine if there has been a change in its operating efficiency and/or damage to its control systems.

6.2.9 Maintainability and Reliability Evaluation

Evaluate the maintenance-related factors of the test item as described in MTP 10-2-507 with emphasis on the following:

- a. Organizational (O), Direct Support (F), and General Support (H) Maintenance requirements.
- b. Operator through General Support Maintenance literature.
- c. Repair parts.
- d. Tools.
- e. Test and handling equipment.
- f. Calibration and maintenance facilities.
- g. Personnel skill requirements.
- h. Maintainability.
- i. Reliability.
- j. Availability.

6.2.10 Safety

Determine the safety characteristics of the test item as described in the applicable sections of MTP 10-2-503 and as follows:

a. Throughout the conduct of the test, test personnel shall observe and record the following:

- 1) Safety hazards, if any, and probable cause
- 2) Steps taken to alleviate safety hazards

b. Personnel shall examine the test item to ensure that as a minimum it contains the following safety shutdown items in its safety control system:

- 1) Flame safety control for ignition, main burner(s) or pilot failure.
- 2) Boiler limit for temperature or pressures in steam or hot water.
- 3) Safety shutoff valves for failure in fuel lines.
- 4) Pressure regulator for burner cycling in response to steam pressure.
- 5) Feedwater regulator for failure in delivery of feedwater.
- 6) Draft loss for disruption in the delivery of air.
- 7) Power failure for loss of electrical power.

c. The test item shall be examined and any discrepancies in the following safety features shall be noted:

- 1) Electrical parts shall be so located or enclosed so that suitable protection against accidental contact with uninsulated energized circuits is provided.
- 2) All internal wiring shall be protected against heat and contact with moving parts.
- 3) Where connections are made to internal wiring a barrier type terminal board or equivalent shall be used for secure lead attachments and protection against accidental contact of leads attached adjacent to each other.
- 4) Where line cords are used they shall be of sufficient current carrying capacity, shall be protected against rubbing at access ports by insulated bushings and shall be sufficiently strain relieved to withstand approximately five pounds of pull.
- 5) Where line fuses are used they shall be of a value consistent with the requirements of the boiler.
- 6) Where switches are used they shall be of sufficient current capacity and mounted so as not to allow movement.
- 7) All metal parts shall be electrically bonded and grounded to prevent static electrical buildup.
- 8) The materials used in the motors and boiler shall be inherently nonflammable and nonexplosive.
- 9) Where the normal operating temperature of the motor(s) shall be sufficient to cause a burn the motor shall have a plate attached stating this fact.

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- 10) All moving parts of the set shall be enclosed to avoid accidental contact when the boiler is in its operating position.
- 11) All propellers or impellers shall be securely attached to the motor shafts.
- 12) All external surfaces and internal surfaces (those exposed during maintenance) shall have no sharp edges.
- 13) Where a thermal overload is provided for a motor it shall be tested for operation and the method of reset (manual or automatic verified).
- 14) The blades or impellers and shafting shall be sufficiently strong and designed with adequate clearance to prevent contact with casings or prevent distortion under conditions of deposit loading or other factors.
- 15) Where capacitors are used they shall be housed in a suitable enclosure which will provide protection and also prevent the emission of flame or molten material in the event of a failure.

6.2.11 Human Factors Evaluation

6.2.11.1 General Evaluation

Throughout the test, evaluate the effectiveness and characteristics of the man-item interaction as related to human factors by performing the applicable sections of MTP 10-2-505 and the following:

a. Prepare checklists to evaluate the human factor characteristic using Human Factors Evaluation Data for General Equipment (HEDGE) for the Class IIIC equipment, including the following:

- 1) Operability:
 - a) Controls and indicators - location, visibility of markings sufficient for proper control of the test item.
 - b) Installation and attachment of external lines and ducts.
- 2) Maintainability:
 - a) Malfunction indication and determination of cause.
 - b) Access to defective component.
 - c) Replacement and/or repair of defective component
 - d) Adjustments and routine maintenance of test item
- 3) Transportability:
 - a) Test item supplied with handles or other lifting attachments for moving.
 - b) Removal of internal or external components for transport.
 - c) Breakdown and reinstallation of the test item.

b. Evaluation of the tasks of step a shall include but not be limited to the following:

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- 1) Title of task conducted
- 2) Adequacy of instructions and tools to perform task
- 3) Ease of performing task
- 4) Design of test item as it affects the task
- 5) Time and personnel required for task

6.2.11.2 Noise Evaluation

6.2.11.2.1 Preparation for Test

a. Determine the measuring locations for the microphone around the test item, using the following criteria:

- 1) The test item shall be in its normal operating position as in 6.2.4.
- 2) There should be no obstructions between the measuring microphone and the test item.
- 3) Measuring locations for the microphone shall be approximately every 20° along a circular path whose radius is approximately ten feet from the approximate geometric center of the test item.
- 4) No measurements should be taken at plus or minus 30° with respect to the normal leading to an open inlet or outlet.

b. Encase the microphone in a sound absorbing enclosure which will be open only on the side facing the test item to minimize indirect reflections.

c. Set up a sound level-meter and octave filter set.

6.2.11.2.2 Test Conduct

a. Calibrate the Sound Level Meter and set the weighting network switch to the "flat response" or C position.

b. Determine the highest sound pressure level in each band over all the bands at each location, (Table I) with the test item operating at a normal level.

c. With the test item inoperative, determine the ambient noise level for the point of highest sound pressure in each band.

6.2.12 Value Analysis

a. Throughout the test examine the design and construction of the test item from a value standpoint in an effort to effect cost reduction of the test item. In particular the following possibilities should be considered:

- 1) Deletion of ineffective or unnecessary features or components.
- 2) Substitution of less expensive but comparable component or material.
- 3) Changes in design of the test item in order to reduce the cost of manufacturing.

b. The proposals resulting from the test should not result in a lowering of the performance and safety characteristics of the test item.

c. Record the following for all items being considered:

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- 1) Component or feature involved
- 2) Suggested change
- 3) Reasons for suggestion

TABLE I
Series 2 Frequency Analysis

BAND	FROM	TO	CENTER FREQUENCY*
1	45	90	63
2	90	180	125
3	180	355	250
4	355	710	500
5	710	1400	1000
6	1400	2800	2000
7	2800	5600	4000
8	5600	11,200	8000

*Defined as geometric mean of cut-off frequencies

6.3 TEST DATA

6.3.1 Preparation for Test

6.3.1.1 Arrival Inspection

6.3.1.1.1 Packaging Inspection

Record the following:

- a. Deficiencies in preservation and packaging, based on MIL-B-3180
- b. Evidence of packaging damage or deterioration
- c. Deficiencies in container marking, based on MIL-STD-129
- d. Identification markings including:

- 1) Name of contractor
- 2) Date of manufacture
- 3) Other pertinent information

e. For each package:

- 1) Weight in pounds.
- 2) Dimensions in feet and inches.
- 3) Cubage in ft³.
- 4) Contents of package - should include mechanical and electrical

drawings and manuals containing installation, operation, and maintenance data.

6.3.1.1.2 Inventory Check

Record the shortages between the contents of the packages and the Basic Issue Items List (BIIL).

6.3.1.1.3 Test Item Inspection

Record the following:

- a. Evidence of defects in:
 - 1) Manufacturing
 - 2) Material
 - 3) Workmanship
- b. Evidence of damage.
- c. Evidence of wear.
- d. Discrepancies between data on accompanying printed material and test item markings.
- e. Deficiencies in identification markings based on MIL-STD-130.
- f. Presence of instruction plates, including:
 - 1) Identification, name and serial number
 - 2) Caution instructions
 - 3) Service instructions
- g. Features not in compliance with applicable ASME, UL, NEMA, National Electric Code Standard requirements, etc.

6.3.1.2 Physical Characteristics

Record data collected as described in the applicable sections of MTP 10-2-500 and the following:

- a. Materials not protected against corrosion and/or are not non-flammable.
- b. Surfaces not treated in accordance with MIL-T-704.
- c. Surfaces not insulated in accordance with MIL-I-12819.

6.3.1.3 Pre-Operational Inspection

Record the following:

- a. Difficulties in assembling the test item
- b. Ease of removal of preservatives
- c. Items requiring lubrication, if any
- d. Any unsatisfactory condition and adjustments required
- e. For each control system:

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- 1) Type (programming, safety, combustion)
- 2) Mode of operation (manual, automatic, combination)

6.3.2 Test Conduct

6.3.2.1 Preliminary Electrical Measurements

6.3.2.1.1 Power Cables -

Record verification of the following:

- a. Adequacy of grounding
- b. That each power lead, of the cable, is not grounded

6.3.2.1.2 Motors

Record the following for each motor:

- a. Motor under test (fan, refrigeration, etc.)
- b. Motor type (universal, induction, etc.)
- c. Direct current resistance of each winding in ohms
- d. Insulation resistance in megohms:
 - 1) Between each winding and the case.
 - 2) Between each winding and all other circuits connected to the case.

e. Dielectric strength between each winding (and its associated circuit) and all other windings and their associated circuits connected to ground, in megohms.

6.3.2.1.3 Fuel Oil Electric Heaters -

Record the following of each heater as indicated in MIL-H-22577:

- a. Insulation resistance in megohms
- b. Dielectric strength in megohms

6.3.2.2 Strength and Tightness

Record the following, as applicable:

- a. For hydrostatic check of watersides:
 - 1) Method used in hydrostatic check
 - 2) Time in minutes
 - 3) Pressure in psia
- b. For pneumatic test of air passages:
 - 1) Time in minutes

2) Pressure in psia

c. For pneumatic test of gas sides:

- 1) Time in minutes
- 2) Pressure in psia

d. For hydrostatic test of fuel oil system:

- 1) Time in minutes
- 2) Pressure in psia

e. For pneumatic test of gas fuel system:

- 1) Time in minutes
- 2) Pressure in psia

6.3.2.3 Operation

a. Record the check of, and proper operation of each control system, and any difficulties.

b. For safety device test, record:

- 1) Identity of each device
- 2) Type of failure the device should detect
- 3) That the device operates as intended

6.3.2.4 Performance

6.3.2.4.1 Preparation for Tests

Record the following:

- a. The type of generator and test to be used.
- b. The condition and cleanliness of the heat transfer surfaces.
- c. The high heat value of each fuel to be used, in BTU per unit of volume or weight.
- d. The length of the test to be conducted, in hours.
- e. The types and locations of sensors attached to the boiler.
- f. Boiler rated capacity, in pounds of steam per hour, or in BTU per hour.

6.3.2.4.2 Test Conduct (Input-Output Method) -

Record the following:

a. For efficiency determination:

- 1) Fuel delivery rate, in units of volume or weight per unit of time.
- 2) For each heat credit:

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- a) Identity of heat credit
- b) Heat content, in BTU
- c) Delivery rate, in BTU per hour
- 3) Water flow input, in gallons per minute.
- 4) Feedwater temperature, in degrees F.
- 5) Feedwater pressure, in psia.
- 6) Steam mass flow, in pounds per hour.
- 7) Steam temperature, in degrees F.
- 8) Steam pressure, in psia.
- b. For steam quality determination:
 - 1) Weight of moisture in steam, at saturation temperature
 - 2) Weight of dry steam
- c. For capacity determination:
 - 1) Main steam mass flow, in pounds per hour
 - 2) Reheat steam mass flow, in pounds per hour
 - 3) Heated water flow, in gallons per minute

6.3.2.4.3 Test Conduct (Heat Loss Method) -

Record the following:

- a. For efficiency determination:
 - 1) Fuel delivery rate, in units of volume or weight per unit of time.
 - 2) For each heat credit:
 - a) Identity of heat credit
 - b) Heat content, in BTU
 - c) Delivery rate, in BTU per hour
 - 3) For each heat loss:
 - a) Identity of heat loss
 - b) Heat loss, in BTU per pound, as fired fuel
- b. For capacity determination:
 - 1) Output water temperature, in degrees F.
 - 2) Output water flow, in gallons per minute

6.3.2.5 Electromagnetic Interference

Record electromagnetic interference data collected as described in the applicable sections of MIL-STD-462.

6.3.2.6 Durability

Record durability data collected as described in the applicable sections of MTP 10-2-502 and the following:

- a. Test performed (24 hour, endurance, etc.)
- b. Duration of test, in hours
- c. Test item operating capacity in percent of rated capacity
- d. For each hour of run:
 - 1) Hours of test (1, 5, 20, etc.)
 - 2) Air flow rate in CFM and temperature in °F
 - 3) For fuel delivery:
 - a) Rate in units of volume or weight, per unit of time
 - b) Temperature in °F
 - c) Pressure in psia
 - 4) Feedwater deliver rate in GPM and temperature in °F
 - 5) Output (steam or hot water):
 - a) Delivery rate in CFM or GPM
 - b) Temperature in °F
 - c) Pressure in psia
 - 6) Stack gas flow rate in CFM and temperature in °F
 - 7) Electrical power consumption in watt-hours
 - 8) Other boiler readings, as appropriate
- e. At the completion of testing, when applicable:
 - 1) Electrical data collected as described in paragraphs 6.2.1.2 and 6.2.1.3.
 - 2) Evidence of deterioration and accelerated wear.

6.3.2.7 Balance Test

Record the following:

- a. Location of measuring point
- b. Vibration level at each measuring point

6.3.2.8 Transportability

Record the following:

- a. Data collected as described in the applicable sections of MTP 10-2-503.
- b. For each test performed, as applicable:
 - 1) Identity of test

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- 2) Evidence of damage or deterioration
- 3) Electrical data collected as described in paragraph 6.2.1
- 4) Operation data collected as described in paragraph 6.2.3
- 5) Performance data collected as described in paragraph 6.2.4

6.3.2.9 Maintainability and Reliability Evaluation

Record data collected as described in the applicable sections of MTP 10-2-507.

6.3.2.10 Safety

Record the following:

- a. Data collected as described in the applicable sections of MTP 10-2-508.
- b. For safety control system:
 - 1) Mandatory controls not included
 - 2) Non-mandatory controls included
 - 3) Suggestions for additional controls
- c. Safety hazards encountered and probable cause.
- d. Steps taken to alleviate safety hazards.
- e. For safety features:
 - 1) Missing safety features
 - 2) Inadequate safety features
 - 3) Non-operable safety features
 - 4) Recommendations for additional safety features

6.3.2.11 Human Factors Evaluation

6.3.2.11.1 General Evaluation -

- a. Record data collected as described in the applicable sections of MTP 10-2-505.
- b. Retain completed checklists.

6.3.2.11.2 Noise Evaluation

Record the following:

- a. A diagrammatic layout of the boiler site showing the locations at which measurements were taken.
- b. The highest noise level in each band over all bands at each measuring location and the corresponding ambient noise levels at each of these frequencies with the test item inoperative.
- c. A list of "out of tolerance" readings where they exist for each band.

6.3.2.12 Value Analysis

Record the following:

- a. Component or feature involved
- b. Suggested change
- c. Reasons for suggestion

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 General

a. Data obtained from all subtests covered by applicable MTP's shall be summarized, compared with the technical performance characteristics specified in the QMR's, SDR's, or other specifications, and evaluated according to procedures described in those applicable MTP's. Appropriate charts, graphs, and tabulated summaries shall be used to present the data in a clear manner.

b. Calculations shall be performed as specified by the individual MTP's, wherever applicable, and all photographs, motion pictures, and illustrative material shall be suitably identified.

6.4.2 Preliminary Electrical Tests

Present the results of the test in tabular form indicating for each motor, its winding, resistance, insulation resistance and dielectric strength test completion. Show results of insulation resistance and dielectric strength tests for all other circuits.

6.4.3 Strength and Tightness

Summarize the results of the hydrostatic and pneumatic tests on air, fuel and water lines by showing the length of the test, leakage if present and loss of pressure.

6.4.4 Operation

Summarize the results of the tests on control systems by listing each system's performance as satisfactory or unsatisfactory. Where unsatisfactory show reasons.

6.4.5 Performance

6.4.5.1 Efficiency

a. Calculate the efficiency of the Input-Output Method as follows:

- 1) Calculate the average value for each credit over the test run and add the average values to obtain Hc.
- 2) Assign the parameter HHV to the high heat value of fuel used and W its mass rate of flow.
- 3) Obtain the output by referring to the Power Test Code. This

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will be a summation of terms of the following type:

$$(HW)_i = W_i - \Delta H_i$$

where:

W_i is the mass rate of flow of steam or water

ΔH_i is the enthalpy difference across the components

- 4) Sum all H_w values to obtain HW and determine efficiency as follows:

$$\text{Efficiency (\%)} = \frac{HW}{HHV - W + H_c} \times 100$$

b. Calculate the efficiency of the Heat Loss Method as follows:

- 1) Calculate H_c as described in a.1 above.
- 2) Obtain HHV and W as described in a.2 above.
- 3) Obtain the total loss (L) in the system from the individual losses given in the Power Test Code and determine efficiency as follows:

$$\text{Efficiency (\%)} = \left(100 - \frac{L}{HHV - W + H_c} \right) \times 100$$

6.4.5.2 Capacity

Capacity (BTU/time) = (mass rate of flow of steam or water in pounds/time)
(enthalpy in BTU/pound)

6.4.5.3 Steam Quality

Steam quality of steam generators (%) = weight of vapor/weight of steam
and water

6.4.6 Electromagnetic Interference

Tabulate the results as required, in accordance with MIL-STD-461A.

6.4.7 Durability

a. Prepare a table presenting the values for each set of readings taken, the sets being in chronological order. Evaluate the total table and circle those values which show a marked increase from the value recorded in the prior set. Analyze the circled readings to determine a possible malfunction of the test item.

b. Record the results of the dielectric strength test. Denote failures.

c. Calculate the final temperature, t_f , for each motor winding as follows:

$$t_f = \frac{R_{t_1}}{R_1} (C + t_r) - C$$

where:

t_r = room temperature of the winding in °C

R_{t_1} = the final resistance value of the winding, in ohms

R_1 = the initial resistance value of the winding, in ohms

C = 234.5 for copper windings and 221 for aluminum windings

d. Compare the temperature rise with the insulation class to determine the allowable temperature rise.

Class A insulation - not more than 40°C rise

Class B insulation - not more than 60°C rise

Class C insulation - not more than 15°C rise

e. List indicators of accelerated wear as indicated by the visual inspection.

6.4.8 Safety

A Safety Release Recommendation shall be submitted in accordance with USATECOM Regulation 385-6, based on the data collected related to safety.

6.4.9 Human Factors Evaluation

Prepare a table showing measurement locations, the highest noise readings in each band and the ambient noise. Include a column for corrected noise readings with the new readings to be determined in the following manner:

- If the difference between the noise reading and the ambient reading is 3 decibels or less mark corrected reading "indeterminate".
- If the difference is between 4 and 10 decibels consult Table II.
- If the difference is greater than 10 decibels no corrections necessary.

Circle those readings which are out of limit by consulting HEL Standard S-1-63B, Maximum Noise Level for Army Materiel Command Equipment, June 1965.

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TABLE II

Corrections for Ambient Sound Pressure Levels

Difference in decibels between
sound pressure level measured
with sound source operating
and ambient sound pressure level
alone.

	4	5	6	7	8	9	10
Correction, in decibels, to be subtracted from sound pressure level measured with sound source operating to obtain sound pressure level due to sound source alone.	2.2	1.7	1.3	1.0	0.8	0.6	0.4

APPENDIX A

MOTOR DIELECTRIC STRENGTH TESTS

General Requirements: This specification is applicable before and after a prolonged run period. The frequency of the test voltage shall be 25-60 HZ and the peak value shall be the specified test voltage multiplied by $\sqrt{2}$. The test voltage shall be applied for (1) minute except that an equivalent test can be conducted for (1) second if the test voltage is 1.2 times that voltage used for the (1) minute test.

Motor Types

- A. Universal Motors - The high potential test for all motors regardless of horsepower and for operation upon circuits not exceeding 250 volts shall be made by applying 900 VRMS.
- B. Direct Current and Induction Motors -
 - 1. Motors rated $\frac{1}{2}$ horse power and larger.
 - a. Apply 1000 VRMS plus twice the rated voltage of the motor windings.
 - b. For motors with armatures or rotors with insulated windings not connected to the line apply 1000 VRMS.

Exception: The standard test voltage for secondary windings of wound rotors of induction motors shall be 1000 VRMS plus twice the maximum voltage induced between slip rings on open circuit at standstill (or running if under this condition the voltage is greater) with primary voltage applied to the stator terminals as in service. Since the voltage induced in the rotor is a function of both the speed of the rotor and the voltage impressed on the stator, the test voltage applied to the rotor shall be determined from that combination of those two conditions which give the highest voltage induced in the rotor.

For reversing motors the test voltage shall be 1000 VRMS plus four times the maximum voltage induced between slip rings on open circuit at a standstill with rated primary voltage applied to the stator terminals.

- 2. Motors Rated at Less Than $\frac{1}{2}$ Horsepower
 - a. For motors rated less than $\frac{1}{2}$ horsepower and operated by circuits of less than 250 volts the test voltage shall be 900 VRMS. Above 250 volt operation the test voltage shall be 1000 VRMS plus twice the motor rated voltage.
 - b. For motors rated less than $\frac{1}{2}$ horsepower where armatures or rotors

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have insulated windings not connected to the line the test voltage shall be 900 VRMS.

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